CIM AND MANUFACTURING SYSTEMS
IE 650 Advanced CIM
Prof. Abdulrahman Al-Ahmari

System Definition

system could be characterised by four attributes:
1. Assemblage. A system involves a group of distinguishable units.
2. Relationships. A system group should have relationships between these units.
3. Goal seeking. A system should perform determined functions or aim at a number of objectives.
4. Adaptability to environment. A system should adapt to its surroundings or external environments.
System Classifications

• McMillan and Gonzalez (1973) classified systems using three perspectives: natural or man-made, systems can be open or closed, and systems can be adaptive or non-adaptive.
• Systems have also been classified using their component relationships or environmental status (dynamic and static).
• A manufacturing system is an example of a complex system with many objectives and involving many internal sub-systems and components. This work will concentrate on the internal working of a manufacturing facility.

Manufacturing Systems

• The original meaning of the word ‘manufacturing’ was ‘to make things by hand’ (manu factum) (Hitomi 1994).
• Nowadays, the meaning of manufacturing is different, the term means the transformation of raw materials into finished products.
### Historical Development of Manufacturing

<table>
<thead>
<tr>
<th>Date</th>
<th>Manufacturing Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancient times</td>
<td>Wheel, lever, pulley, cutting implements, assemblies e.g. water wheel, carts.</td>
</tr>
<tr>
<td>Middle ages</td>
<td>Windmill, mechanical clock.</td>
</tr>
<tr>
<td>Pre 1800</td>
<td>Completely custom – craftsman.</td>
</tr>
<tr>
<td>1800s</td>
<td>English system – Introduction of general purpose machines that could be used for a variety of products.</td>
</tr>
<tr>
<td>1900s</td>
<td>Pre-specified worker motion – moved the control totally to the hand of management.</td>
</tr>
<tr>
<td>1913</td>
<td>Moving assembly line for Ford Model T.</td>
</tr>
<tr>
<td>1924</td>
<td>Mechanised transfer line for machining automobile engine components in England.</td>
</tr>
<tr>
<td>1946</td>
<td>First electronic digital computer (ENIAC).</td>
</tr>
</tbody>
</table>

#### Additional Details:

- **1950s**
  - Numerical Control (NC) machine developed at MIT.
  - Identical procedures produce different results on same machine at different times. Emphasised outliers instead of mean performance.
  - First industrial robot designed.

- **1960s**
  - Solid state integrated circuit developed
  - First Unimate robot installed to unload parts in die-casting operations.
  - Automatically Programmed tooling (APT) Developed, a programming language for NC machines.
  - First flexible manufacturing system installed.

- **1970s**
  - Combination of the versatility of general purpose machines with the precision and control of special purpose machines.
  - Microprocessor developed.
  - Computer language for programming industrial robots developed.

- **1980s**
  - Computer Integrated Manufacturing developed
  - Cellular Manufacturing Systems appeared.

- **1990s**
  - Agile Manufacturing /Mass Customisation
  - Virtual Manufacturing Systems
Basic aspects of manufacturing system definitions

Types of Manufacturing Systems

Manufacturing systems can be classified into several types based upon a variety of schemes identified in the literature. Using these schemes, manufacturing systems can be classified according to:

1. Time function of manufacturing process output
2. Transformation of natural resources (or manufacturing operations).
3. Types of transformation process
4. Production volume
5. Production planning and inventory policies
6. Workflow (or system structure).

Types of Manufacturing Systems

1. Time function of manufacturing process output
   • Continuous systems involve the continuous production of product (chemicals, plastics, petroleum and food industries)
   • Discrete manufacturing systems involve the production of individual items (cars, machine tools and computers)
Types of Manufacturing Systems

Transformation of natural resources

3. Types of transformation process

- **Assembly system**: joins individual parts or components in sub-assemblies or final assemblies.
- **Non-assembly type**: materials are processed to produce individual parts or components. This type includes machining, moulding, fabrication, etc.
Types of Manufacturing Systems

4. Production volume

- **Mass production system** produces a high volume of products and is characterised by its special purpose equipment.
- **Batch manufacturing system** is characterised by small batches produced. The goal of batch manufacturing is often to meet continuous customer demand on general purpose equipment. This type of manufacturing system is a very important part of manufacturing industry. It has been estimated that 75% of the UK and USA manufacturing products are produced using batch manufacturing systems (Papadopoulos et al. 1993).
- **Jobbing manufacturing systems** involves low production often to meet specific customer orders.

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Types of Manufacturing Systems

5. Production planning and inventory policies (production strategies)

- Make-To-Order (MTO)
- Engineer-To-Order (ETO)
- Assemble-To-Order (ATO)
- Make-To-Stock (MTS)
MTS & MTO manufacturing systems (Al-Ahmari 1998)

Types of Manufacturing Systems
6. Workflow (or system structure).

• job shop,
• project shop,
• cellular system
• flow line.
Job Shop Manufacturing System

Project Shop Manufacturing System
Types of manufacturing systems

- Proj. shop
- Jobbing System
- Job shop
- Batch System
- Cellular
- Mass System
- Flow

ETO MTO ATO MTS

Comparisons of manufacturing systems

<table>
<thead>
<tr>
<th>Factor</th>
<th>Project shop</th>
<th>Jobbing</th>
<th>Batch &amp; Cellular</th>
<th>Mass &amp; Flow line</th>
<th>Continuous production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility of the process</td>
<td>High</td>
<td>Variable</td>
<td>Many</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Number of set-ups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>Small</td>
<td></td>
<td>General</td>
<td>Special</td>
<td></td>
</tr>
<tr>
<td>Dominant utilisation</td>
<td>Universal</td>
<td></td>
<td></td>
<td>Plant</td>
<td></td>
</tr>
<tr>
<td>Control of operations</td>
<td>Complex</td>
<td></td>
<td>Very complex</td>
<td>Straight</td>
<td></td>
</tr>
<tr>
<td>Operation times</td>
<td>Long</td>
<td></td>
<td></td>
<td>Forward</td>
<td></td>
</tr>
<tr>
<td>Capacity control</td>
<td>Difficult</td>
<td></td>
<td></td>
<td>Easy</td>
<td></td>
</tr>
<tr>
<td>Productivity control</td>
<td>Difficult</td>
<td></td>
<td></td>
<td>Easy</td>
<td></td>
</tr>
<tr>
<td>Bottlenecks</td>
<td>Many</td>
<td></td>
<td></td>
<td>Few</td>
<td></td>
</tr>
<tr>
<td>Amount of capital investment</td>
<td>Low/High</td>
<td></td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Finished part inventory</td>
<td>Low</td>
<td></td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>WIP</td>
<td>High</td>
<td></td>
<td></td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Product/service range</td>
<td>High</td>
<td></td>
<td>Very high</td>
<td>Low</td>
<td>Standard</td>
</tr>
</tbody>
</table>

Quantity
Comparisons of manufacturing systems

<table>
<thead>
<tr>
<th>Finished part inventory</th>
<th>WIP</th>
<th>Production/service range</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>High diversity</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Fixed position layout</td>
<td>Process layout</td>
<td></td>
</tr>
<tr>
<td>Cell layout</td>
<td>Product layout</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Product layout</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Production strategies and manufacturing lead times

<table>
<thead>
<tr>
<th>Manufacturing lead times</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETO</td>
</tr>
<tr>
<td>MTO</td>
</tr>
<tr>
<td>ATO</td>
</tr>
<tr>
<td>MTS</td>
</tr>
<tr>
<td>Assembly</td>
</tr>
<tr>
<td>Subassembly</td>
</tr>
<tr>
<td>Final assembly</td>
</tr>
</tbody>
</table>

Design | Manufacturing
Enterprise Organization (overview)
Basic functions of manufacturing systems for small and medium-sized production lots

Long-range forecasting

Mathematical models
Forecasting algorithms
Standard data

Input
Management goals and objectives
Customer behavior
Demographic developments
Product innovations
New manufacturing processes
Available labor
Raw material supply
Finance market
Economic situation
Competition

Activity
Analysis of:
market potential
competition
product line
resources supply
new facilities
capital supply

Output
Product line
Annual sales
Profit objectives
Plans for:
facilities
processes
labor
raw material
utilities
transportation
Sources of capital
Cash requirement
Capital equipment and facility planning

Input
- Product line
- Parts spectrum
- Manufacturing processes
- Transportation facilities
- Warehouse facilities
- Control strategies
- Computing facilities
- Software systems

Activity
- Selection of: facilities
- Distribution system
- Manufacturing methods
- Manufacturing equipment
- Manufacturing alternatives
- Quality assurance system
- ROI calculation

Output
- Manufacturing facility layout
- Machine tools
- Auxiliary equipment
- Transportation systems
- Control computer system
- Planning and control programs
- Layout of plant
- Communication system
- Quality control hardware
- ROI results

Engineering and design activities

Input
- Workpiece related features
- Features data
- Geometric data
- Physical data
- Performance data
- Functional data
- Manufacturing data
- Material supplier data

Activity
- Determination of product features
- Functions design
- Material selection
- Calculation of product parameters (kinematic, dynamic, stress, strain, aerodynamic, etc.)
- Selection of: coding system, part families
- Generation of: drawing, bill of materials, process plan, QC plan, NC program

Output
- Drawing
- Bill of materials
- Product documents
- Process plan
- NC program
- Product reliability
- QC procedures
Manufacturing process planning

Input
- Part description
- Part classification
- Bill of materials
- No. of parts ordered

Activity
- Generative process planning
- Variant process planning

Master file: machine tools, tools, fixtures
- Master machining process and sequences file
- Products variants file
- Machining parameters
- Manufacturing times

Output
- Machining processes
- Machining sequences
- Machining parameters
- Machine tools
- Tools
- Machining times and cost

Sales activities

Input
- Product model mix
- Orders and due dates
- Quality standards
- Sales strategies
- Pricing strategies

Activity
- Determination of:
  - Product performance parameters
  - Product features
  - Prices
  - Promotion strategy
  - Profit plan
  - Delivery data

Product specification
- Sales planning and pricing algorithms
- Distribution models
- Machining know-how
- Inventory

Output
- Product:
  - Specification
  - Performance
  - Price
  - Delivery data, delay
  - Proceeds
Manufacturing resource scheduling

Input:
- Parts ordered
- Due dates
- Parts classification

Activity:
- Scheduling of:
  - Materials
  - Production lots
  - Manufacturing equipment
  - Time phasing

Output:
- Make/buy decision
- Machine assignments
- Tools and fixture assignments
- Route assignments
- Number of parts to be:
  - Made in-house
  - Taken from inventory
  - Made by vendors

Purchasing and receiving activities

Input:
- Material requirements
- Material specifications
- Due dates
- Preferred vendors

Activity:
- Materials and parts purchasing
- Receiving
- Inspection
- Vendor rating

Order processing procedures:
- Vendor performance file
- Inventory master database
- Quality control procedures
- Quality standards

Output:
- Requests for quotation
- Purchase orders
- Delivery dates
- Received orders
- Quality reports
- Reorders
- Vendor rating
- Inventory update
Functions of inventory management

Input
- Parts and materials on order, net requirements
- Lead times: purchasing, manufacturing
- Cost of material ordered
- Inventory carrying cost
- Order cost

Activity
- Calculation of:
  - Inventory
  - Inventory adjustment
  - Economic order quantity
  - Order dates

Output
- Parts: released, release date
- Material: ordered, order date
- Order due dates
- Economic lot sizes
- Adjusted inventory

Quality control functions

Input
- Product identification
- Process identification
- Parameters to be tested
- Upper and lower limits

Activity
- Calculation of:
  - Product performance
  - Process trends
  - Quality trends

Test results
- Products: accepted, rejected
- Quality trends
- Quality history
- Cost of quality control
- Process performance
Order scheduling and control requires the synchronization of information flow with material flow

The CIM Process

- **Step 1: Assessment of the enterprise in three areas:**
  - Technology
  - Human Resources
  - Systems
The CIM Process

• Step 2: Simplification – eliminate waste

The CIM Process

• Step 3: Implementation with performance measures
  – Product cycle time
  – Inventory turns by product
  – Production setup times
  – Manufacturing efficiency
  – Quality and Rework
  – Employee output/ productivity
Definitions of CIM

- Engineering Management Philosophy
- A System of Systems
- Integrates People and Technology
- A Network that Does Work

Definitions of CIM

- The integration and co-ordination of design, manufacture and management using computer-based systems". Tie and Cilin 1992.

- “A computer integrated system involving overall and systematic computerization of the manufacturing process. Such systems will integrate computer aided design, computer aided manufacturing and computer aided engineering, testing, repair and assembly by means of a common database". ESPRIT definition 1982 (cited by Browne et al. 1988).
Definitions of CIM

- “The application of information and manufacturing technology, plans and resources to improve the efficiency and effectiveness of a manufacturing enterprise through horizontal functional and external integration”.

  MeGaughey and Roach (1227)

- “CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organizational and personal efficiency”

  Rehg and Kreabber 20QIJ

Benefits of CIM

- More Profits
- Reduce Labor
- Increase Machine Use
- Reduce Scrap and Rework
- Increase Manufacturing Capacity
- Reduce Inventory
- Shorten New Product Development Time
- Fewer Missed Delivery Dates
- Decreased Warranty Costs
- Consistent Products
Benefits, continued

- Manufacturing Records
- Manufacturing Data
- Reduced Training Costs
- Higher Employee Morale
- Safer Working Environment

- Improved Customer Image
- Greater Scheduling Flexibility
- Recruit new employees
- Increased Job Security/More Marketable

Benefits, continued

- More Opportunities to Upgrade Skills
- Less Floor Space
- Managed Quality
- Optimized Products
- Controlled Inventory
- Scheduling Improvement

- Fewer Machines
- Fewer People
- Fewer “things to go wrong”?
- Others
- Others
- Others.
CIM components

CIM includes all the functional areas of manufacturing organization. Each functional area should be integrated with the others. The major components of CIM are:

- Computer Aided Design (CAD)
- Computer Aided Process Planning (CAPP)
- Computer Aided Manufacturing (CAM)
- Computer-Aided Inspection (CAI)
- Production Planning and Control (PP&C),
CIM models and concepts

CIM concept for Siemens AG.

The digital equipment corporation CIM model
Various modes of factory data exchange.

The hierarchical planning and control concept
• The first layer → the engineering and design functions where the product is designed and developed. The output of this activity is the drawings and the bill of materials.

• The second layer → the process plans for manufacturing, assemblies and testing are made. (Process plans + drawings + BOMs + customer orders) are the input to scheduling. The output of scheduling is the release of the order to the manufacturing floor.

Manufacturing is controlled by a hierarchically structured real time computer systems.

The operations of machine tools and material movement equipment are monitored by a data acquisition system.

Most of the standardization efforts in product design are concerned with providing interfaces for connecting various CAD systems and for integrating them with product planning. The most important of these activities are:

• IGES, Initial Graphics Exchange Specification
• SET, Standard d’Exchanges et de Transfert
• VDAFS CAD (VAD-Flachsetzung), Interface of the German Association of Automobile Manufacturers
• CAD* ESPRIT CAD-Interface
• GKS, Graphical Kernel System
• FFIM, Form Features Information Model
• PDES, Product Data Exchange Specification
• STEP, Standard for the Exchange of Product Model Data

Although there are many researchers working on the concept of a product model, so far there are few results which are useful to industry. The difficulties are due to too many variations of product and manufacturing methods. The endeavor of building a product model will be more successful when models are more tailored to specific product classes.
Data processing tasks of the central computer.

1. Planning of the manufacturing job
   - Order planning
   - Tool and fixture selection
   - Machine tool selection
   - Workpiece route assignment
   - Machine programs selection
   - NC programs
   - Robotic programs
   - Test programs
   - Dialog support for planning
   - Dialog support for task and workpiece setup

2. Execution of the manufacturing job
   - Initialization of the manufacturing run
   - Machine program loading
   - Offset correction
   - Machine control
   - Machine monitoring
   - Tool monitoring
   - Tool adjustment
   - Material flow control
   - Workpiece tracking
   - Dialog for monitoring the job execution

3. Reporting the manufacturing runs
   - Quality data
   - Piece rate
   - Manufacturing times
   - Machine performance
   - Down time
   - Repair time

4. Communication with subordinate computer
Data processing tasks of the control computer:

1. Operation of the machine tool
   - Loading and execution of the NC program
   - Adaptive control
   - Controlling of the machine tool peripherals
   - Dialogue support of shop floor programming
   - Dialogue support of the simulation of the machine tool operation

2. Monitoring of the machine tool
   - Collection of operating data on parts
   - Collection of setup and repair information
   - Automatic diagnosis of machine tool
   - Support of interactive machine diagnosis

3. Communication with supervisor computer

A computer network for CIM
Discussion

• What do understand by Manufacturing systems engineering Concepts?
• Why is Manufacturing Important for KSA?
• What are the research trend in classification of manufacturing systems?